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Guilt in the eyes: Eye movement and physiological evidence for guilt-induced social avoidance

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ABSTRACT

Guilt is widely acknowledged as an exemplary social emotion that is unpleasant but has positive interpersonal consequences. Previous empirical research focuses largely on documenting the behavioral consequences of guilt; less is known about the psychophysiology of experiencing guilt. Here we designed an interactive paradigm and asked participants to play multiple rounds of a dot-estimation task with two partners. Failure in the task, either due to the participant or due to the partner, would cause electric shocks to the partner. In Experiment 1, we asked the participant to watch video clips depicting the partner's facial expressions while the partner was receiving pain stimulation. Eye movement recording showed that the participant fixated less on the partner's eyes but more on the nose region in the participant-caused pain (high guilt) condition than in the partner-caused pain (low guilt) condition, an indication of social avoidance. In Experiment 2, we asked the participant to either fixate on the eye (Eye Group) or the nose region (Nose group) of the partner and recorded their skin conductance during the viewing. We found that the Eye Group exhibited higher skin conductance response in the high guilt condition than in the low guilt condition and such a difference was absent for the Nose Group, indicating that the forced eye contact with the victim enhanced the emotional arousal of guilt. The life-like interactive paradigm is thus able to demonstrate the mutual dependence between eye contact and social emotions: eye contact both elicits and is regulated by emotional content in social interaction.

> It was this eye contact with "the Jew" that humanized him and made this scene unbearable to Zakis. The intimacy of locking eyes with a dying person overwhelmed him emotionally. No other perpetrator in my sample spoke of making eye contact and such an intimate recognition of shared humanity.[1] Katharina von Kellenbach *The Mark of Cain*

1. Introduction

Why do perpetrators try to avoid direct eye contact with their victims? One possibility is that eye contact may trigger feelings of being judged and accused, which is particularly salient for those who are guilty about their acts. This conjecture is in line with a large body of field studies and laboratory experiments showing that the presence of eye or eye-like images increases people's concern about morality and altruism (Ekström, 2012; Powell, Roberts, & Nettle, 2012). Although a large number of empirical studies have demonstrated the interpersonal nature and behavioral motivations of guilt (Baumeister, Stillwell, & Heatherton, 1994; Giner-Sorolla, 2013; Tangney, Stuewig, & Mashek, 2007; Xu, Begue, & Shankland, 2011), none has identified physiological responses of guilt during social interaction and its impact on social communicative behavior. Thus, we have not achieved an empirically examined account of the bodily expressions or gestures of interpersonal guilt during social interaction. To this end, it is important to elicit guilt in a naturalistic, life-like social context (Hari, Henriksson, Malinen, & Parkkonen, 2015; Schilbach et al., 2013;

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[1] Von Kellenbach, K. (2013). *The mark of Cain: Guilt and denial in the post-war lives of Nazi perpetrators*. New York NY: Oxford University Press.

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Schilbach, 2014), which is missing in most of the previous laboratory-based studies of guilt. The aim of the current study is to test the hypothesis in a naturalistic, life-like context that interpersonal guilt leads to social avoidance of eye contact and that eye contact with the victim induces emotional arousal in transgressors.

Eyes are often compared to the "windows of soul" (e.g., "These lovely lamps, these windows of the soul" in Du Bartas' *La Semaine*), especially in the context of social interaction (Emery, 2000; Guillon, Hadjikhani, Baduel, & Rogé, 2014; Khalid, Deska, & Hugenberg, 2016; Pfeiffer, Vogeley, & Schilbach, 2013; Senju & Johnson, 2009). Just like information can go in and out through a window, this metaphorical comparison to eyes is also bidirectional. On the one hand, the pattern of eye gaze (e.g., direct vs. averted) reflects the cognitive and affective states (e.g., aggressive vs. submissive) of the agent, and is an integral part of facial expression (Adams & Kleck, 2005; Bolmont, Cacioppo, & Cacioppo, 2014; Frith, 2009; Jack, Blais, Scheepers, Schyns, & Caldara, 2009). On the other hand, the eyes bring in important information to the agent during social interaction and communication, such as another person's identity, emotional state, and even focus of visual attention. Appropriate use of gaze to gather information in social contexts is an important social skill that plays a crucial role in social cognition and interpersonal interaction (Emery, 2000). In real-time face-to-face social interaction, the most important source of information concerning the interactive partner's mental states is his/her eyes. Reduction or failure in fixating on the interactive partner's eyes (i.e., making eye contact), a type of social avoidance, may lead to difficulty and distortion in recognizing other's emotional and cognitive states. This has been demonstrated in people with social communicative problems, such as individuals with autism spectrum conditions (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Batson, Fultz, & Schoenrade, 1987; Pelphrey et al., 2002; Wang et al., 2016), alexithymia (Bird, Press, & Richardson, 2011), and amygdala lesions (Adolphs, Baron-Cohen, & Tranel, 2002; Adolphs et al., 2005; Spezio, Huang, Castelli, & Adolphs, 2007). During natural vision these two aspects of eye gaze are mutually and dynamically related: the pattern of eye gaze both modulates and is modulated by the input visual information. Neurally, it has been shown that neurons in primate amygdala are responsive both when the eye of another individual falls on the fovea and when the primate direct its fixation away from the another individual's eye region, indicating the close link between the perception of and response to other's eyes at the neurobiological level (Mosher, Zimmerman, & Gothard, 2014; for human neuroimaging study, see Gamer & Büchel, 2009).

To date, most of the research has excluded the social interaction context from eye gaze and primarily treated the gaze as a modulator of face perception (for review, see Senju & Johnson, 2009). This line of research has consistently showed that compared with face images with averted gaze, face images with direct gaze towards the participants are detected faster in visual search (Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008). Similarly, the identity (Macrae, Hood, Milne, Rowe, & Mason, 2002), gender (Hood, Macrae, Cole-Davies, & Dias, 2003), and emotional expression (Bindemann, Mike Burton, & Langton, 2008; Vuilleumier & Pourtois, 2007) of those images with direct gaze are more easily identified than images with averted gaze. A common issue for these studies is that the face stimuli are socially unrelated to the participants and there is no meaningful social interaction between the faces and the participants. The stimuli and tasks are to some extent artificial and decontextualized such that participants are in a position only to passively perceive the visual input and are less likely to engage in life-like social processes (Hari et al., 2015). Thus the psychological processes elicited by such stimuli and tasks may be different from those engaged in real life contexts (Birmingham & Kingstone, 2009; Kagan, in press; Kingstone, 2009; Lee & Siegle, 2014), an issue especially pressing for research on social emotions and social gaze, as they both have important interpersonal functions (Hess, Adams, & Kleck, 2008; Hess & Hareli, 2015) and can only be assessed when the participants are (or at least believe themselves to be) in a social interactive mode (Schilbach et al., 2013).

To address this issue, we examined in two experiments the impact of interpersonal guilt on the pattern of eye gaze/contact (Experiment 1) and how eye contact modulates physiological responses to interpersonal guilt (Experiment 2), following the dichotomy outlined above. In other words, while Experiment 1 focused on the pattern of eye gaze/contact to reveal an exterior expression (cf. Terburg, Aarts, & van Honk, 2012) of the internal state of guilt (i.e., the expression side of the dichotomy), Experiment 2 went one step further to show the emotional arousal elicited by making eye contact in a guilt context (i.e., the perception side of the dichotomy). In other words, Experiment 1 focused on the pattern of eye gaze/contact to guilt-inducing stimuli to reveal an exterior expression (e.g., averted eye gaze; cf. Terburg et al., 2012) of the internal state of guilt (i.e., the expression side of the dichotomy). Going one step further, Experiment 2 analyzed the emotional arousal elicited by making eye contact in a guilt-inducing context (i.e., the perception side of the dichotomy). Specifically, Experiment 2 investigated how the position of eye fixation may serve as a gate to the perception and processing of socio-affective information and modulate physiological responses (i.e., arousal) in a social interactive context.

To summarize the theoretical background outlined above: 1) guilt stems specifically from social interaction with one's victim, over and above the information about the suffering of another individual; one's responsibility in causing the victim's suffering distinguishes guilt from general forms of empathy for suffering (cf. Clarke, 2016), and 2) eye contact is one of the most frequently adopted and straightforward channels of social interaction (Emery, 2000; Senju & Johnson, 2009; Wang & Adolphs, 2017). Based on this theoretical background and our experimental design, we hypothesized that, 1) when viewing the victim's face freely, the participants will fixate less on the victim's eye region in the guilt compared to the control condition (Experiment 1), and 2) the guilt-induced emotional arousal, as measured by skin conductance, should be higher for the participants required to fixate on the victim's eye region compared to participants required to fixate on the victim's nose region (Experiment 2).

2. General method

2.1. Stimuli

Eight silent video clips by four confederates (two females) were used in the two experiments. In each clip, the partner (confederate) of the interactive game placed his/her head on a chin-rest and made painful expressions while receiving electric shocks. Each clip consisted of four consecutive episodes, each lasting for 15 s. In the first 5 s of each episode the confederate had a neutral and static expression while in the last 10 s the confederate received continuous electric shocks and was asked to naturally express their painful feeling. The whole clip ended with additional 1 to 5 s of the neutral face of the confederate, such that the video did not end abruptly after the fourth painful episode. Thus, each video clip lasted a total of 61 to 65 s. Facial features were positioned approximately in the same place on the screen (Fig. 1B). Each confederate was videotaped in two instances, corresponding to the two blocks in which the partner (i.e., confederate) received pain stimulations (see below). The display resolution of videos was $600 * 400$. The videos were played at a rate of 30 frames per second.

A full Latin-square procedure was used to assign the video stimuli into 4 test versions, in which the order of confederates (two male confederates for the male participants, or two female confederates for the female participants) and the order of conditions (guilt vs. control, see below) were counterbalanced across participants. Each participant encountered only one test version.

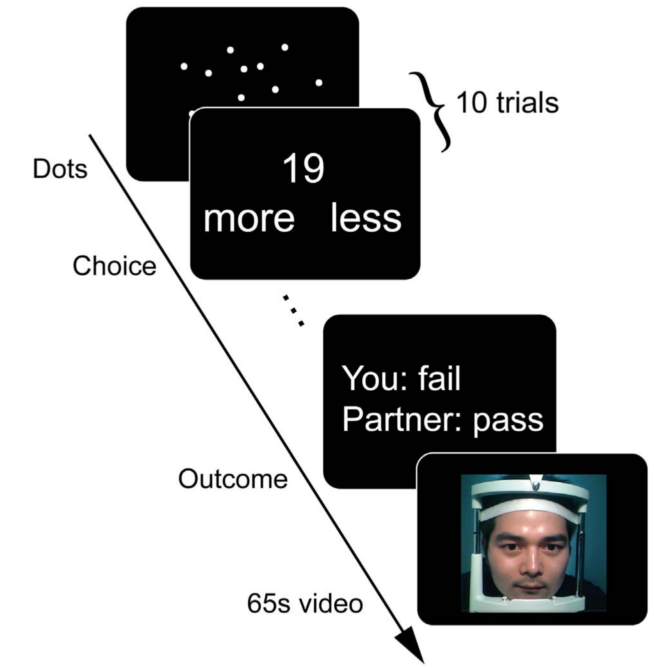

Fig. 1. Experiment procedure and task sequence. Each participant interacted with 2 partners (i.e., confederates) for 4 blocks each. At the beginning of each block, one player (the participant or the partner) was randomly selected to (potentially) receive pain stimulation if one (or both) of them failed the dot-estimation task in the current block. In each block, the participant and the partner performed 10 trials of the dot-estimation task, after which their performance feedback was presented. If at least one of the players committed five or more incorrect responses in the task, the pair failed the current block, and the person who was selected at the beginning of the block would receive pain stimulation after the experiment. Note: Face image is from one of the authors' colleagues and is used with permission.

2.2. Procedures

Each participant came to the laboratory individually. Upon arrival the participant met a confederate of the same sex and was told that four players, including the participant and this confederate, would participate in an interactive game through intranet, but in separate rooms. The participant was told that in order to eliminate the influences of familiarity and social distance, the confederate who met the participant did not interact with the participant. The participant was also told that all the other players had the same sex as the participant.

Participants were informed that they may receive unpleasant electric shocks in the experiment although the shocks could not cause any permanent damage to their skin. Then an intra-epidermal needle electrode was attached to the left wrist of the participant for cutaneous electrical stimulation (Inui et al., 2002). Participant-specific pain threshold was calibrated. Participants were asked to rate the intensity of a series of pain stimulations on a scale of 1 ('not painful') to 8 ('unbearable'). They then received pain stimulation with level 6 intensity for four 10-s periods, separated by a 5-s interval between the two consecutive periods. They were told that anyone who had to receive pain stimulation during the game would receive the electric shock with the same duration and subjective intensity as they experienced. This procedure was to familiarize the participants with the pain stimulation and to increase the verisimilitude of the situation. In fact, as predetermined in our experiment protocol, participants would not receive any pain stimulation in the formal experiment.

Each participant interacted with two confederates sequentially, each in four blocks. Each block contained 10 rounds of dot-estimation task (Fig. 1). If any one of the two players failed to achieve six or more correct responses, one player, who was ostensibly randomly chosen before each block, had to receive pain stimulation. The participant was chosen in half of the blocks and the partner was chosen in the other half.

Performance feedback of each block was predetermined by a computer program. In the two blocks in which the participant was chosen to receive pain stimulation, both players achieved six or more correct responses and thus the participant did not receive pain stimulation. In the two blocks in which the partner was chosen, the partner always received electronic shock, one block was the participant's fault (Guilt condition) and another block was the partner's own fault (Control condition). In the two 'partner' blocks, the participant watched the video clip in which the partner received the pain stimulation. The participant watched two videos of each confederate per condition. There was a brief rest period between the blocks. The participant's eye movements (Experiments 1 and 2) and skin conductance (GSR; Experiment 2) were recorded. Calibration for eye-tracking was performed on a nine-point grid before recording. After each experiment, participants completed a post-test manipulation check. Specifically, participants rated, on a 7-point Likert Scale, their feelings of guilt and anxiety in each condition, and indicated how much pain they would like to share for the partner (as compensation). The compensation here is hypothetical; the participants never received pain stimulation after the task. In these studies, we report all measures, manipulations, and exclusions.

2.3. Experiment 1 method

2.3.1. Participants

Sample size was determined before any data analysis. To this end, we used G*Power 3 software (Faul, Erdfelder, Lang, & Buchner, 2007), which showed that we needed a sample size of at least 34 for this study to have adequate power ($1 - \beta > 0.80$) to detect a small to medium-size effect ($|\text{slope}| = 0.4$). Forty undergraduate and graduate students participated in this experiment. Failure in the post-experiment manipulation check (i.e., failure in retrieving the identity of the two partners) and errors in eye-tracking calibration led to the exclusion of 8 participants from the data analysis, leaving 32 participants in the data analysis (16 female; age ranging from 19 to 24 years; mean age 21.7 years). Participants all had normal or corrected-to-normal vision. Informed written consent was obtained from each participant before the experiment. This experiment was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the School of Psychological and Cognitive Sciences, Peking University.

2.3.2. Apparatus and measures

Eye movements were recorded with an EyeLink 2000 system at a sampling rate of 500 Hz. Each video clip was presented at the middle of a 21-inch CRT screen ($1024 * 768$ resolution; frame rate 100 Hz). Participants watched each clip with their head positioned on a chin rest 65 cm from the screen. All recordings and calibrations were based on the left eye but viewing was binocular. After the experiment, the participant also completed the Guilt and Shame Proneness questionnaire (GASP; Cohen, Wolf, Panter, & Insko, 2011) as a measure of trait guilt.

2.3.3. Data analysis

Eye movement data were extracted from a 65-s interval starting at the beginning of the video clip. Three areas on the video clip were drawn as areas of interest (AOI), including the eyes, the nose, and the non-eye-or-nose face areas, to capture the core features of the face (Fig. 2A; cf. Auyeung et al., 2015). As the video clips were recorded with the confederate's position fixed, these areas of interest were stable across frames for each clip. It should be noted that the size varied across these AOIs and across confederates (see Table 1 for the size of each AOI). However, as we were interested in how experimental condition (Guilt vs. Control) modulated the eye movement measures within each AOI, and because the use of confederates were counterbalanced across participants, the variation in size was irrelevant to our analysis and

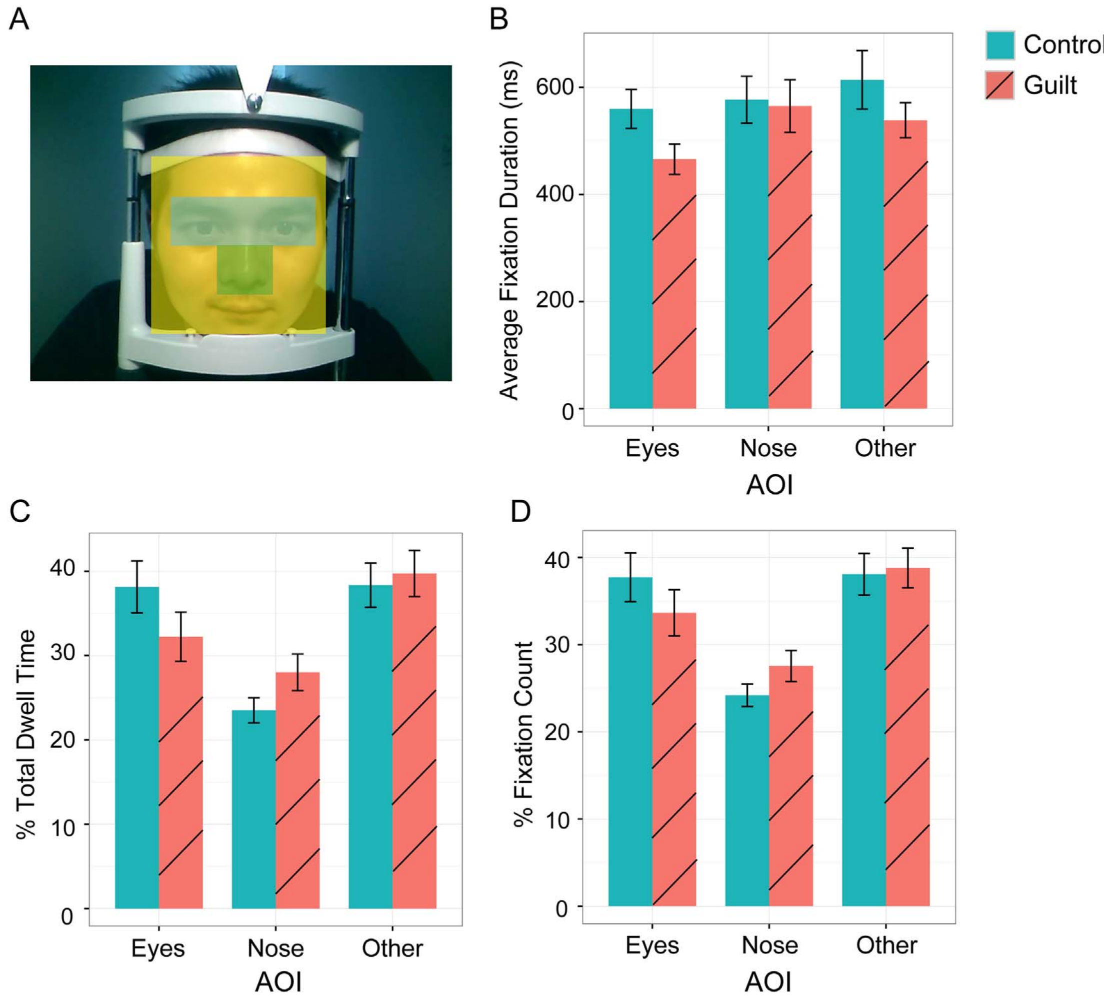

Fig. 2. Results of the eye movement measures. (A) Definition of the area of interest (AOI). Average fixation duration (B), percentage of total dwell time (C), and percentage fixation count (D) for each AOI as the function of the guilt condition (Guilt vs. Control). Note: Face image is from one of the authors' colleagues and is used with permission.

Table 1
Absolute area of the areas of interest (AOIs).

AOI	Female confederate	Male confederate
Eye	200 × 60	220 × 75
Nose	80 × 70	85 × 75
		85 × 80
Face	220 × 235	265 × 270

Note: width × height (pixels).

statistical inference.

Three eye movement measures were analyzed: total dwell time, fixation count, and average fixation duration. Total dwell time was the sum of the durations of all the fixations made within an AOI during the whole video-viewing period. Fixation count was the number of fixations detected on an AOI during the whole video-viewing period. Average fixation duration was the average amount of time spent on each fixation and was calculated by dividing total dell time over fixation count within a specific AOI. For easier comparison between these measures, we transformed the absolute values to percentages. Specifically, we divided the fixation count/total dwell time in each AOI by the total fixation count/ total dwell time in the whole face area, respectively, during the video viewing period. We used the *lmer* program of the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) in the R environment for statistical computing (R-Core Development Team, 2011). Statistical inference was based on a linear mixed model (LMM) for percentage dwell time, fixation count, and average fixation duration (Bates, 2010), with fixed factors for condition (Guilt vs. Control) and crossed random effects for identity of participants and identity of the confederate the participants saw in the video. We included the random effects to regress out any potential confounding between-participant and between-confederate variance. Estimates larger than 1.96 ∗ *SE*, i.e., absolute *t*-values larger than 1.96, were interpreted as significant at the 5% confidence level.

2.4. Experiment 2 method

2.4.1. Participants

Experiment 2 had a between group factor, i.e., the position of fixation (eye vs. nose). Sample size was determined before any data analysis. To this end, we used G*Power 3 software (Faul et al., 2007), which showed that we needed a sample size of at least 21 for each group to have adequate power ($1 - \beta > 0.80$) to detect a small to medium-size effect ($|\Delta slope| = 0.08$). Twenty-four undergraduate and graduate students (12 female; age ranging from 18 to 25 years; mean age 21.3 years) were tested for the Eye Group, another twenty-four (12 female; age ranging from 18 to 26 years; mean age 21.5 years) were tested for the Nose Group. Participants were matched for gender and age across groups. They had normal or corrected-to-normal vision and had not participated in Experiment 1. Informed written consent was obtained from each participant before the experiment.

2.4.2. Procedures

Essentially the same procedure in Experiment 1 was used, except

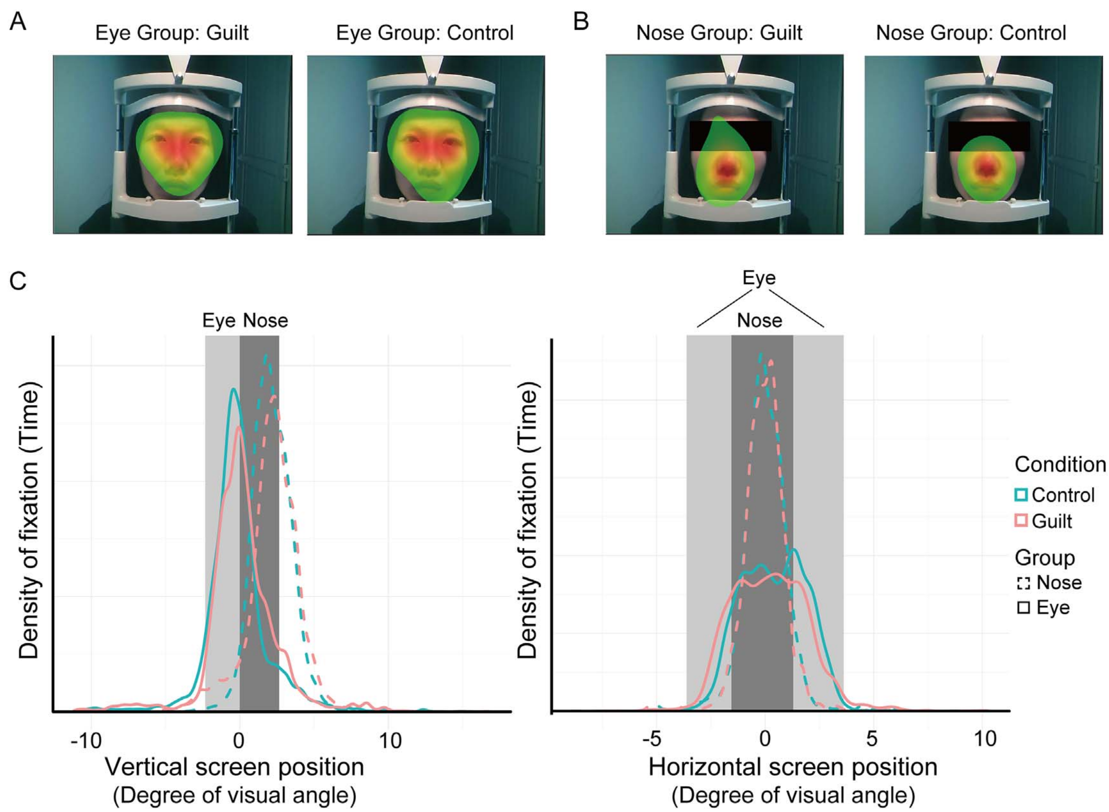

Fig. 3. Fixation patterns (heat maps) of Experiment 2. Heat maps illustrate the location and total dwell time (from low in green to high in red) of fixation for the Eye (A) and Nose (B) Group in Experiment 2. Panel C illustrates the distribution of vertical (left panel) and horizontal (right panel) fixation density. The fixation density is shown as a function of deviation from the screen center. Positive numbers on the *x*-axis indicate positions below (left panel) or right of (right panel) the center. Note: Face image is from one of the authors' colleagues and is used with permission. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Results of post-test manipulation check (Experiment 1).

Item	Guilt condition	Control condition	t
Guilt	5.8 (0.2)	2.4 (0.3)	9.81***
Anxiety/distress	4.6 (0.4)	3.1 (0.3)	5.34***
Sharing pain (intended compensation)	3.2 (0.1)	2.3 (0.1)	6.98***

*** $p < 0.001$.

that in Experiment 2 the participants were asked to keep their fixation on the partner's eyes (Eye group) or nose (Nose group) when they watched the video clips. For the Nose group, the videos were slightly adjusted so that the victim's eyes were covered by a black rectangle to prevent participants from accidentally seeing the partner's eyes. The same eye tracking system as described above was used to make sure that the participants' fixation was kept on the target areas (see Fig. 3). We calculated the distribution of participants' fixation density (total dwell time on each position during the video) along horizontal (x) and vertical (y) axes. Specifically, the 0 for the x-axis is the middle of the eye region, and the 0 for the y-axis is the border between eye and nose regions. This position was defined as the screen center.

2.4.3. *Acquisition and analysis of the skin conductance (GSR) data*

While the participants watched the video clips, their skin conductance level was continuously recorded with an MP150 psychophysiological monitoring system (BioPac Systems, Santa Barbara, CA). Two shielded Ag-AgCl electrodes, filled with standard NaCl electrolyte gel, were attached to the distal phalange of the index and ring fingers of the participant's left hand. Signals were amplified and were sampled at 1000 Hz. For each participant, we extracted the GSR data from the first 60 s of recording, which covered the whole range of the 4 stimulation phases. Before statistical analysis, we first resampled the GSR data so that every 1000 data points (i.e., 1 s) from the original data set were averaged to a single data point. Then we normalized the data using square root. The transformed data were used as the dependent variable in a linear mix regression model, where we included group (Eye vs. Nose), condition (Guilt vs. Control), time (1st to 60th second), and gender of the participants (male vs. female) as fixed factors and the identity of participants and identity of the confederate the participants saw in the video as random effects.

3. Results

3.1. *Experiment 1*

3.1.1. *Rating results*

Table 2 summarizes the self-reported feelings in the post-experiment manipulation check. Participants felt guiltier and more anxious, and were willing to share more pain for the partner when the participants failed in the task and caused pain to the partner, compared with when the partner caused the pain.

3.1.2. *Eye movement results*

Measures for all three areas of interest (AOIs) are shown in Table 3 and Fig. 2. Preliminary analyses revealed no significant main effect of gender or interaction between gender and condition on any eye movement measures. Thus we collapsed across gender in the following analyses. When the GASP score and its interaction with guilt condition were included in the regression model for eye movement measures, no significant interaction effect was found.

3.1.2.1. *Eye region.* Analysis of normalized total dwell time indicated

Table 3
Eye movement results of Experiment 1.

		Guilt	Control	*t*-Value
Eyes	%TD	32.2 (2.9)	38.2 (3.1)	− 2.09*
	%Fix. Count	33.6 (2.7)	37.7 (2.8)	− 1.57
	Avg Fix Dur	466 (28)	560 (36)	− 2.35*
Nose	%TD	28.0 (2.2)	23.5 (1.5)	2.41*
	%Fix. Count	27.6 (1.8)	24.2 (1.3)	2.36*
	Avg Fix Dur	565 (49)	577 (43)	< 1
Other	%TD	39.7 (2.7)	38.3 (2.6)	< 1
	%Fix. Count	38.8 (2.3)	38.1 (2.4)	< 1
	Avg Fix Dur	539 (33)	614 (55)	− 1.47

Note: %TD: normalized total dwell time; %Fix. Count: normalized fixation count; Avg Fix Dur: average fixation duration. Numbers in the bracket indicate standard error.
* $p < 0.05$.

that participants looked at the victim's eyes significantly less in the Guilt than in the Control condition (32% in Guilt condition and 38% in Control condition), $b = -0.03$, $SE = 0.01$, $t = -2.09$ (Fig. 2C). Similarly, average fixation duration for the Guilt condition (466 ms) was significantly shorter than that for the Control condition (560 ms), $b = -47.32$, $SE = 20.18$, $t = -2.35$ (Fig. 2B). Normalized fixation counts showed a similar tendency but did not reach significance, with an average of 34% in the Guilt condition and 38% in the Control condition, $b = -0.02$, $SE = 0.01$, $t = -1.57$ (Fig. 2D).

3.1.2.2. Nose region. In this region, the Guilt condition yielded significantly longer looking time, as revealed in normalized total duration (28% for Guilt condition vs. 23% for Control condition), $b = 0.02$, $SE = 0.01$, $t = 2.41$. A similar pattern was observed on normalized fixation count, with more fixations in the Guilt condition compared with the Control condition (28% for Guilt condition vs. 24% for Control condition), $b = 0.02$, $SE = 0.01$, $t = 2.36$. No significant difference was found on average fixation duration, $t < 1$.

3.1.2.3. Other face region. No significant difference was found on this region for the total dwell time and the fixation count measures, $ts < 1$. Average fixation duration showed a marginally significant effect, with shorter duration in the Guilt condition (539 ms) compared with the Control condition (614 ms), $b = -37.82$, $SE = 25.76$, $t = -1.47$.

3.2. Experiment 2

3.2.1. Rating results

Table 4 summarizes the self-reported feelings and the levels of pain the participants were willing to share in the post-experiment manipulation check. Essentially the same pattern of results was observed for both groups of participants, i.e., felt guiltier, more anxious, and were more willing to share pain for the partner when the participants failed in the task and caused pain to the partner, compared with when the partners caused the pain by themselves. This indicates that our manipulation of guilt was successful for both groups. Interestingly, for the Guilt condition, the Eye group participants rated higher on guilt than the Nose group, $t(46) = 2.10$, $p = 0.042$, although the group-by-condition interaction did not reach significance, $F(1, 46) = 1.79$, $p = 0.19$. This lack of power is not surprising because the emotion ratings were collected after the online task and the effect of gaze area on guilt may have already faded by then. So we rely more on the online physiological measure of emotional arousal, i.e., the skin conductance level, to make inferences.

Table 4
Results of post-test manipulation check (Experiment 2).

Item	Eye group ($n = 24$)		Nose group ($n = 24$)	
	Guilt	Control	Guilt	Control
Guilt	6.5 (0.2)	2.0 (0.3)	5.7 (0.4)	2.0 (0.3)
Anxiety/distress	5.3 (0.4)	3.2 (0.4)	4.3 (0.4)	3.3 (0.3)
Sharing pain (intended compensation)	2.5 (0.1)	1.3 (0.2)	2.5 (0.1)	1.4 (0.2)

Note: numbers in the bracket indicate standard error.

3.2.2. Eye movement

Fig. 3 shows the fixation patterns of the two groups of participants. As can be seen from the heat maps (Fig. 3A and B), the fixation centers for both groups were within their required areas, i.e., eyes and nose, respectively. As the difference between the eyes and the nose was exhibited mainly in the vertical axis, we used two-sample Kolmogorov-Smirnov test to compare the distributions of fixation positions along the vertical axis. The results revealed no difference between the Guilt and Control conditions in either group, $ps > 0.05$, while the difference between groups was significant, $p = 0.002$ (Fig. 3C). This indicated that the participants followed our instruction for gaze positions.

3.2.3. Skin conductance results

We focused on whether the emotional arousal of guilt (vs. control), as measured by skin conductance level, was modulated by the position of fixation (eye vs. nose), and whether such modulation was gender-specific. The regression analysis showed that the three-way interaction between group, condition, and gender was significant, $b = 0.38$, $SE = 0.08$, $t = 4.55$, and the two-way interaction between group and condition was also significant, $b = 0.98$, $SE = 0.08$, $t = 11.78$. This indicated that although male and female participants showed a similar trend for the modulatory effect of fixation position on guilt-induced GSR (Fig. 4A and C), they differed in the degree of the modulation. We thus carried out two separate regressions for the Nose group and the Eye group. For the Eye group, the interaction between guilt condition (Guilt vs. Control) and gender was significant, $b = 0.90$, $SE = 0.13$, $t = 6.76$. We split the Eye group according to the gender of the participants (Fig. 4B) and found that the difference in GSR between Guilt and Control conditions was larger for the male participants ($b = 2.22$, $SE = 0.18$, $t = 12.25$) than for the female participants ($b = 0.42$, $SE = 0.19$, $t = 2.16$). For the Nose group, no significant gender by condition (Guilt vs. Control) interaction was found, $t < 1.5$ (Fig. 4D). The main effect of condition was significant, $b = -0.65$, $SE = 0.10$, $t = -6.54$, such that the guilt condition elicited lower GSR than the control condition. The main effect of gender was not significant, $b = 0.43$, $SE = 0.89$, $t = 0.48$. These results indicate that the physiological responses and thus the arousal of guilt was modulated by the position of fixation, and such modulatory effect, although present for both genders, manifested itself more prominently in males.

4. Discussion

In two experiments with an interactive paradigm, we demonstrated that interpersonal guilt reduced the transgressor's fixation on the victim's eye region while the victim was enduring the harm caused by the transgressor (Experiment 1). Moreover, the transgressors who were forced to fixate on the eye region of the victim who was enduring the harm evidenced higher physiological responses to guilt than those who were forced to fixate on the nose region (Experiment 2). These findings contradict some of the previous theoretical speculations that social emotions such as guilt and gratitude may not have strong emotional arousal and identifiable expressions (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2015; Keltner & Buswell, 1996). By putting participants in an interactive context and confronting them with their victim, we observe strong emotional arousal and consistent eye gaze patterns associated with guilt and further demonstrate that these two aspects are closely related to each other.

The interactive interpersonal paradigm adopted here and in a few previous studies (e.g., Koban, Corradi-Dell'Acqua, & Vuilleumier, 2013;

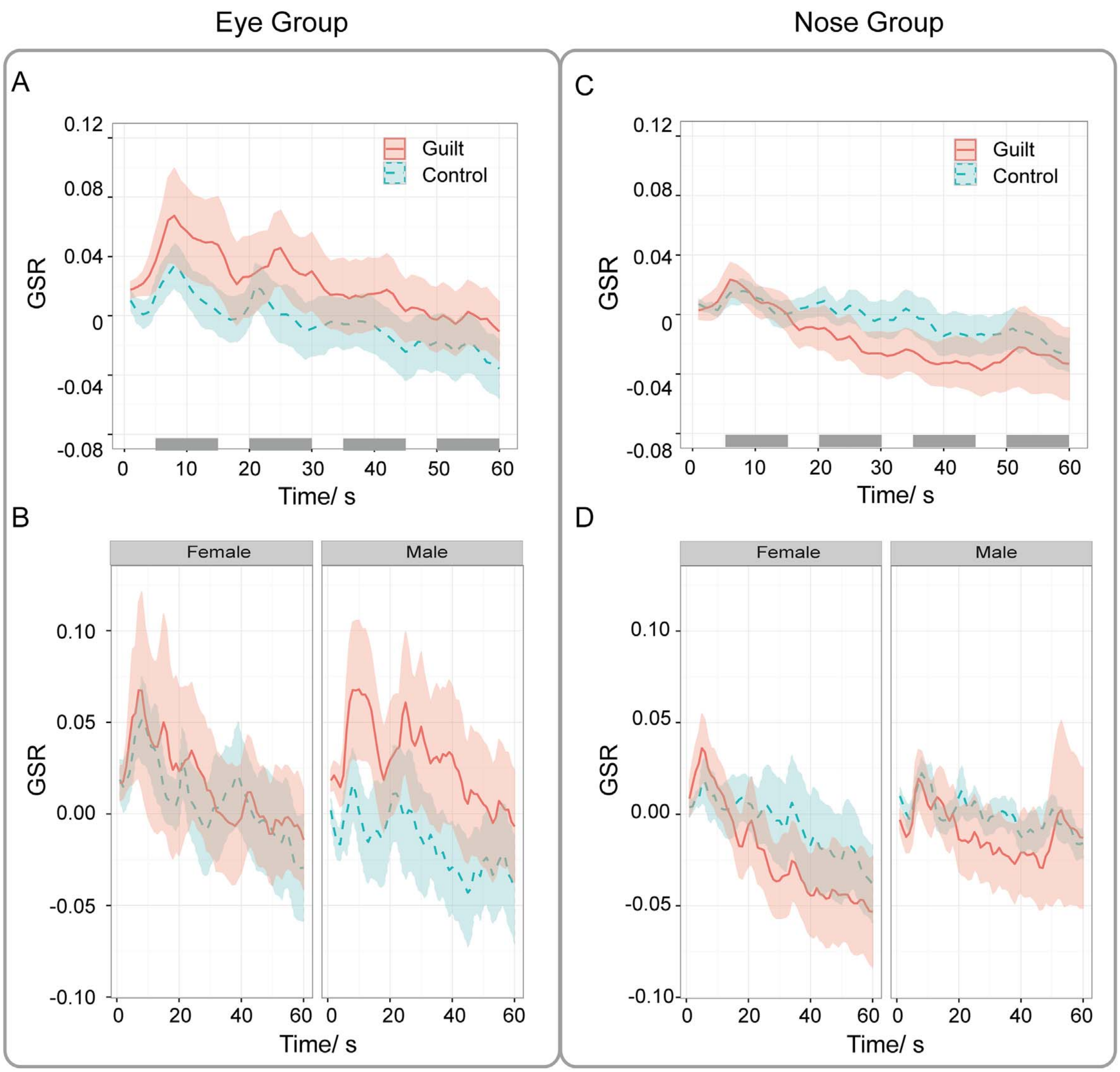

Fig. 4. Results of the skin conductance response (GSR). The timecourse of skin conductance level for the Guilt (solid red line) and Control condition (dotted green line) are displayed (A–B: Eye Group; C–D: Nose Group). In the Eye group, GSR was higher for the Guilt condition than for the Control condition; moreover, the difference is more pronounced in male than in female participants. In the Nose group, only the main effect of guilt condition (Guilt vs. Control) was significant; neither the main effect of gender, nor the interaction between guilt condition and gender was significant. Gray rectangles on the x-axis indicate the period in which the partner was receiving pain stimulation. Shaded areas for the skin conductance time course indicate standard errors. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Yu, Hu, Hu, & Zhou, 2014) has the strength of putting participants in a social context, confronting them with (ostensibly) real social consequences of their actions, choices, and decisions. Given that social emotions (e.g., guilt, gratitude) arise in and regulate social interactions (Schilbach et al., 2013), the interpersonal paradigm allows us to investigate the psychological and biological mechanisms of such emotions as they actually occur (rather than in imagination). The advantages of the interactive task enabled the recording of the online dynamics of eye contact patterns and emotional arousal during real social interaction, thus allowing us to characterize for the first time the physiological response profiles of interpersonal guilt.

Eye contact avoidance and enhanced skin conductance responses indicate that the eyes of the suffering victim are perceived by the transgressor as a social threat and trigger negative emotions such as anxiety and fear (Schneier, Rodebaugh, Blanco, Lewin, & Liebowitz, 2011). In fact, the effects in eye contact and skin conductance may be causally related (cf. Helminen, Kaasinen, & Hietanen, 2011): eye contact is avoided because making eye contact with the victim induces negative feelings (arousal). It has been consistently shown that social threat such as public speech (Wager et al., 2009) and negative social evaluation (Akdeniz et al., 2014) engender anxious feelings and heightened physiological responses (Öhman, 2008). However, in the case of guilt, the nature or origin of the anxiety/fear arising from eye contact with the victim is not entirely clear. One possibility is that the victim's eye may (be perceived to) convey negative evaluation, blame, or an intent for retaliation towards the transgressor, which in turn drives the fear and anxious responses in the transgressor. This is in line with the psychoanalytic account of guilt, where guilt is characterized as the fear of the judgment of an authority figure, external or internal (Freud, 2002). Supporting this interpretation, research on social anxiety disorder showed that socially anxious individuals, who perceive more negative evaluations from social interaction compared with non-anxious individuals (Horley, Williams, Gonsalvez, & Gordon, 2003; Lin, Hofmann, Qian, Kind, & Yu, 2016), avoid eye contact during social interaction (Schneier et al., 2011; but see Wieser, Pauli, Alpers, & Mühlberger, 2009).

Another possible origin of the enhancement of emotional responses induced by eye contact with the victim could be the transgressor's empathy for the victim. It has been shown that perceived responsibility increases transgressor's empathy for the victim (Čehajić, Brown, & González, 2009; Zaki, 2014). Empathy for the suffering victim may generate personal distress in the transgressor (Batson et al., 1987;

Singer & Klimecki, 2014), which motivates social avoidance (Shaw, Batson, & Todd, 1994). However, eye contact with the victim may also generate empathetic concerns for the victim, which motivates approach and prosocial behaviors towards the victim, for example in the form of compensation (Ketelaar & Tung Au, 2003; de Hooge, Zeelenberg, & Breugelmans, 2007; Yu et al., 2014). In the current study, we observed both of these tendencies, i.e., avoidance of direct eye contact during the real-time interaction, and willingness to share a portion of the pain for the victim in the offline questionnaires. These findings indicate that different empathetic motivations may be induced by guilt, but they may operate at different time scales.

It is beyond the scope of the current study to dissociate the empathy account from the fear-of-evaluation account for the emotional responses associated with eye contact with the victim because we only included videos of the victim. Future studies can advance in this respect by including a condition in which participants view the video of a disinterested third-party, who has the authority of judging and evaluating the participants but does not suffer from any harm, thus ruling out the possibility of empathy driven motivations (cf. Crockett, Özdemir, & Fehr, 2014). Another way that future studies could advance our understanding of the relationship between eye contact avoidance and guilt-heightened emotional arousal is to use more fine-grained neurobiological measures, such as direct recording of neuronal activity in the brain areas essential for emotion processing (e.g., the amygdala; cf. Mosher et al., 2014). This could offer more information about the causality and temporal structure of these two otherwise highly intertwined phenomena. Moreover, while the current study focused on the expression and emotion of the transgressor's side, it will be interesting to investigate whether the facial expression of guilt (e.g., submissive gaze) can benefit the detection of the internal atonement by the victim and third-party and how such an understanding may facilitate forgiveness and reconciliation (Beyens, Yu, Han, Zhang, & Zhou, 2015; McCullough, Pedersen, Tabak, & Carter, 2014). Furthermore, as social emotions such as guilt and shame are culturally shaped, it is important to understand whether and how cultural difference causes confusions in the perception of social emotions, which in turn may incur cost to the mutual understanding in cross-cultures interactions. Using a promising psychophysical approach, *Reverse Correlation*, Jack et al. has successfully modelled the diagnostic features (2012) for emotional facial expression recognition in different culture group (Eastern Asian vs. Western Caucasian), and revealed and significant difference cross culture (see also Chen, Garrod, Schyns, & Jack, 2015, for mental state, and Chen et al., 2016 for pain and pleasure; see Jack & Schyns, 2017). For example, compared with Western Caucasians, Eastern Asians exhibited a significant confusion between “disgust” and “fear” (Jack et al., 2009) since they bias more towards the eye regions (Jack, Garrod, Yu, Caldara, & Schyns, 2012; Jack et al., 2009). Reverse-engineered diagnostic features have showed an overlap between “fear” and “disgust” in eye regions (i.e. upper lid raiser, Jack et al., 2012). With the innovative reverse correlation method, we can tackle the issues: 1) whether there are any facial features that are consistently informative for guilt, and 2) whether such features are culture invariant (Darwin, 1872/1998).

Given that the skin conductance response (Bechara, Damasio, Damasio, & Lee, 1999; Gupta, Koscik, Bechara, & Tranel, 2011) and eye contact (Adolphs et al., 2005; Spezio et al., 2007; Wang et al., 2014) have consistently been shown to reliably track the neural activity in amygdala, the bearings of the current findings on the neurobiological basis of guilt, especially implication for amygdala, is worth noting. In the neuroimaging literature, evidence for the involvement of amygdala in guilt experience is, at best, weak and mixed. According to a recent meta-analysis of functional neuroimaging studies on guilt, the most consistently recruited brain structures in guilt experience (regardless of induction modality) include the anterior/middle cingulate cortex, dorsomedial prefrontal cortex, insula, and superior temporal gyrus (Gifuni, Kendal, & Jollant, 2016). To the best of our knowledge, only two out of sixteen neuroimaging studies claim to identify guilt-specific activation in amygdala (Berthoz, Grezes, Armony, Passingham, & Dolan, 2006; Michl et al., 2014). However, given the relatively small sample size of these studies (12 and 16, respectively), the reliability of their findings should be taken into consideration.

This being said, we do not mean to exclude amygdala from the processing of guilt (cf. Kagan, 2003). Three issues need to be clarified before one can legitimately discuss the functional relevance of a brain structure (e.g., amygdala) in guilt processing: (1) What aspect or mode of guilt is at stake (Ent & Baumeister, 2017; Yu, Shen, Yin, Blue, & Chang, 2015)? Guilt can be understood as an affective experience elicited by a certain socially relevant event (i.e., cognitive antecedence of guilt; e.g., Yu et al., 2014), or as an anticipatory affective motivation, preventing people from damaging their social relationships and feeling guilt (i.e., guilt-aversion; Chang, Smith, Dufwenberg, & Sanfey, 2011; Charness & Dufwenberg, 2006). (2) What paradigm is adopted to elicit guilt? The guilt experience elicited by scenario imagination (e.g., Berthoz et al., 2006; Takahashi et al.,2004) and by interpersonal interaction (e.g., Koban et al., 2013; Yu et al., 2014) may be subserved by distinct brain networks. (3) What modality is used to measure brain activity? While functional imaging studies with guilt-eliciting tasks do not consistently implicate amygdala in the guilt experience, studies using structural imaging reliably identify structural differences in amygdala between healthy populations and people who are impaired or oversensitive to the experience or anticipation of guilt, namely, people with callous-unemotional trait (Jones, Laurens, Herba, Barker, & Viding, 2009) and people with major depressive disorder (Frodl et al., 2002). After considering the above three issues, it is clear that one cannot rule out the role of amygdala in guilt processing based solely on existing neuroimaging studies. The present study thus advances our understanding about this issue by providing a novel and more life-like paradigm to elicit guilt and measure its neurobiological correlates. The implications of the current study for the role of amygdala in guilt processing is two-fold. First, given that the skin conductance response (GSR) is a direct indicator of amygdala activity (Bechara et al., 1999; Gupta et al., 2011) and that fixating on the victim's eyes produced larger guilt-induced GSR responses than fixating on the victim's nose, it is conceivable that looking into the eyes of a victim may trigger a fear/anxiety-like emotional experience subserved by amygdala. Second, given that elevated activation in amygdala elicited by unexpected eye contact could trigger fixation away from one's eyes and thus avoid uneasy and risky social interactions (Mosher et al., 2014), our finding that fixation on the partner's eye region was reduced in the guilt condition indicates that amygdala may encode an interpersonal emotion regulation strategy for guilt that aims to reduce interpersonal conflict (Baumeister et al., 1994).

It is interesting to consider the current findings in light of a neuroimaging study of interpersonal guilt, where a similar interactive paradigm was used (Yu et al., 2014; see also Koban et al., 2013). In that study, as in the current one, guilt was manipulated by the participant's responsibility in the partner's suffering: higher responsibility triggered stronger feelings of guilt and more compensation behaviors. Through a mediation analysis, Yu et al. (2014) found that the correlation between the neural processing of guilt in the anterior middle cingulate cortex and compensation behavior was mediated by the neural activity in a midbrain nucleus (i.e., periaqueductal gray). As the midbrain has been shown to serve the function of regulating social and physical threat/anxiety (Buhle et al., 2013; Wager et al., 2009), Yu et al. (2014) interpreted the role of midbrain as reflecting the motivation of using compensation to reduce or regulate guilt and the accompanied social anxiety (cf. Estrada-Hollenbeck & Heatherton, 1997). However, in Yu et al. (2014), the participants could not directly observe the victim and were not confronted with explicit evaluation and judgment, nor were they required to interact with the partners after the experiment. In contrast, in the current study, the confrontation with the victim was made more explicit and real. This may more strongly trigger the emotional arousal of guilt, and, as a consequence, the behavioral and physiological responses associated with guilt may more resemble the standard responses to social threat and anxiety (Wager et al., 2009). Taken together, these studies demonstrate that feeling of social threat and anxiety is likely to be a crucial affective component of interpersonal guilt.

A few caveats should be noted. First, in Experiment 2, the participants in the Nose group saw the confederates' eyes covered by a black rectangle, while the participants in the Eye group saw the whole, intact faces. It might be argued that the observed difference in GSR was confounded by the difference in visual information (especially visual information related to the partner's pain expression) available to the two groups of participants. Although a conclusive answer may be possible with further control experiments where either the Nose group participants see the whole, intact face, or the Eye group participants see the nose-covered face, we believe that evidence from research on information processing of facial expression is in favor of our interpretation. Specifically, it has been shown that the cheek and nose contain the most informative features for pain identification (Chen et al., 2016). Therefore, information about the partner's pain expression is no less, if not more, available for the Nose group than for the Eye group.

Another concern is the interpretation of the guilt-induced eye contact avoidance observed in Experiment 1. An alternative interpretation for the downward shift of fixation could be that the participants actively sought and directed fixation to the region most informative of the partner's pain, rather than avoided eye contact with the victim. Although we cannot completely rule out this interpretation, we do find it in contradiction with a number of findings from the interpersonal relationship literature. For example, in an interpersonal helping context, Hein and colleagues found that participants were more likely to reduce the painful electric shocks delivered to an in-group member (a fan of their favorite soccer team), while they were more likely to actively seek to watch an out-group member (a fan of a rival soccer team) enduring electric shocks (Hein, Silani, Preuschoff, Batson, & Singer, 2010). Moreover, watching the out-group member in pain activated the reward system in the participants, which indicates that the participants may take pleasure in the outgroup member's suffering (cf. Lanzetta & Englis, 1989; Takahashi et al., 2009). This motivation and behavioral pattern is unlikely to exist between transgressor and victim in an interpersonal guilt context (Baumeister et al., 1994): the genuinely guilty transgressor is unlikely to seek pleasure in watching the victim suffering.

5. Conclusion

We demonstrate that interpersonal guilt reduces transgressor's eye contact with the suffering victim and systematically shifts the fixation down to the nose region. Such a submissive gesture is likely due to the fact that eye contact with the victim in guilt situations may heighten the emotional arousal of the transgressor. This suggests that interpersonal guilt has social anxiety and fear as its affective content, which may automatically trigger avoidance motivations in social interaction. Findings in this study may in turn explain why the approach motivations of interpersonal guilt (e.g., apology and compensation to the victim and confession to the public) is more difficult to initiate than denying the crime and fleeing from accusation, a contrast that is perfectly illustrated by the mental anguish and struggling conscience of Rodion Raskolnikov in Dostoyevsky's *Crime and Punishment*.

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